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Robinson, James C

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Author(s): James C. Robinson

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would be useful to assess the actual forecasting performance of continuous time series models.

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WORKER RESPONSES TO OCCUPATIONAL RISK OF CANCER

James C. Robinson*

Abstract—Toxicological data from the Registry of Toxic Effects of Chemical Substances and worker exposure data from the National Occupational Health Survey are used to construct an occupational cancer risk index. This objective cancer risk measure is strongly correlated with subjective worker-assessed measures of exposure to health hazards in the 1978–80 Young Men's and Young Women's National Longitudinal Surveys. Workers exposed to occupational health hazards, as measured both by the objective risk index and the subjective risk perceptions, are more likely to quit their jobs than are otherwise comparable workers not exposed to hazards. They also pursue voice strategies, as measured by willingness to vote in favor of union representation.

Public policy in the area of occupational safety and health has developed under the implicit assumption that the self-interested actions of individual workers, labor unions, and managers in an unregulated environment are not adequate to minimize the incidence of work-related health problems, especially chronic health effects such as cancer. In contrast to this rather pessimistic view of the labor market as a source of incen-

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*University of California, Berkeley.

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tives for hazard reduction, a considerable empirical literature has developed documenting the extent to which workers recognize hazards on the job and respond to those perceptions. Both "exit" and "voice" worker strategies have been reported, using data on quit intentions, quits, prounion attitudes, and the extent of union representation. These empirical studies have been limited by the types of data available on working conditions, however, which to date have consisted largely of injury rather than illness rates. As such, these studies are not directly relevant for answering the important question as to the extent to which labor market incentives can act as substitutes for and complements to direct governmental regulation of occupational exposures to chronic health hazards.

This paper uses a unique source of information on the toxicological properties of chemicals used in industry and on the extent of worker exposure to those chemicals to study labor market responses to the risk of work-related cancer. Data on chemical carcinogenicity from the Registry of Toxic Effects of Chemical Substances is combined with exposure information from the 1972–74 National Occupational Health Survey to construct a cancer risk index for 231 three digit occupational groupings. This index is then matched with two national surveys that contain information on worker perceptions of hazard, quits, and prounion attitudes.

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The paper begins with a brief survey of economic models of worker response to health risks in the work-place. The second section discusses the toxicological, exposure, and worker survey data used in the study. Findings are presented in the third section. A final section considers the implications of the analysis for public policy in the area of occupational safety and health.

Exit and Voice Responses to Occupational Hazards

Viscusi (1979) has developed a widely used model for analyzing the process by which workers may come to understand the nature of the health risks they face at work. Viscusi assumes that workers have only vague perceptions of the risks posed by different jobs at the time of hiring, but that their perceptions become more precise over the course of employment based on their personal experiences and those of their co-workers. Workers who come to believe that their jobs pose significantly greater risks than initially conjectured will, in Viscusi's model, be more likely to quit their jobs than otherwise comparable workers whose hazard perceptions do not evolve in this manner.

Duncan and Stafford (1980) develop a model in which interest in unionization on the part of individual workers depends on the extent to which the conditions they face on the job are public goods, affecting all individuals in a similar manner. The presence of such workplace public goods is hypothesized to increase worker interest in unions, since possibilities for successful individual negotiations with management are reduced. This model is clearly applicable to occupational health and safety, since the collective nature of many exposures implies that efforts to improve working conditions often require collective as distinct from individual initiatives. Hills (1985) and Robinson (1988) find that nonunion workers in unsafe jobs report a greater willingness to vote in favor of union representation than comparable workers in safe jobs.

These models can be summarized in the form of three equations:

$$Pr(PERCEIVES = 1)$$

$$= f(HAZARD, DEMOGRAPHICS) \qquad (1)$$

$$Pr(EXIT = 1)$$

$$= g(HAZARD, DEMOGRAPHICS, CONDITIONS) \qquad (2)$$

$$Pr(VOICE = 1)$$

$$= h(HAZARD, DEMOGRAPHICS, CONDITIONS).$$

In (1), *PERCEIVES* is a dichotomous variable taking the value 1 if the worker reports serious risk of work-

related illness and 0 otherwise, HAZARD is a measure of occupational safety and health hazard, and DEMO-GRAPHICS is a vector of worker demographic characteristics assumed to influence the accuracy of the worker's hazard perceptions and the probability that the worker faces exceptionally high risk of injury or illness within his or her occupation. EXIT is a dichotomous variable indicating whether the worker quits, VOICE is a dichotomous variable indicating whether the worker reports intentions to vote for union representation, and CONDITIONS is a vector of job characteristics and working conditions other than risk of occupational illness.

This study employs the basic economic model and econometric specifications developed to study injury risks and applies them to the risks of cancer. Three sets of equations are estimated, corresponding to equations (1) through (3), that describe the determinants of worker hazard perceptions, quits, and attitudes towards union representation.

Data on Workers and Working Conditions

The data used in this study are assembled from three sources. The Registry of Toxic Effects of Chemical Substances (RTECS), compiled by the National Institute of Occupational Safety and Health (NIOSH), provides comprehensive information on the carcinogenic properties of chemicals potentially available in the workplace. The 1972-74 National Occupational Health Survey (NOHS), also conducted by NIOSH, provides information on the extent of exposures to a number of chemicals on the RTECS list. The RTECS and NOHS data are used together to create an index of risk of cancer for each of 231 occupations. This risk index is then matched with the 1978-80 National Longitudinal Surveys (NLS) of young men and young women using three digit Census occupation codes. Each respondent to the NLS is thus ascribed the risk of cancer that is the average for all workers in his or her occupation.

The RTECS is a compilation of published chemical toxicological data, derived from a comprehensive and continually updated review of the international scientific literature. The computerized 1981 version of the RTECS used for this study contains information on positive toxicological effects for 45,156 chemicals. The majority of these effects are derived from studies using nonhuman subjects. The extent to which toxicity data may be validly extrapolated across species is a matter of continuing scientific debate. Governmental regulatory bodies universally accept the basic proposition that evidence of toxicity and, more specifically, of carcinogenicity, in nonhuman animals constitutes strong presumptive evidence of human toxicity and carcinogenicity. The RTECS data are used in this study as the

basis for an "objective" measure of cancer risk in the sense that these data are used in regulatory strategies to control working conditions. The question facing market-oriented policy strategies in occupational health concerns how well the state of the art in the scientific understanding of cancer percolates into the perceptions and actions of individual workers, labor unions, and managers.

The RTECS data base contains information on a variety of toxicological effects of chemical substances, including positive findings that the substances are carcinogenic, neoplastic (causing tumors that neither invade tissues nor metastasize), teratogenic (causing birth defects), mutagenic (causing chromosomal changes), or irritants to skin or eyes. This study is limited to chemicals with positive data on carcinogenicity. The RTECS data are expressed in many nonconformable units. The task of collapsing these data into a single index was performed by the National Institute of Occupational Safety and Health as part of its effort to develop priority rankings for future research and regulatory efforts. The NIOSH methodology is described in detail in Pedersen, Young, and Sundin (1983).

The NOHS was conducted by NIOSH during 1972–74 in order to ascertain the type and extent of exposures to toxic chemicals occurring in the U.S. economy. Specially trained engineers toured 5000 facilities in 67 metropolitan areas and recorded worker exposures by type of chemical, extent to which the exposure was controlled, and whether the exposure was full time or part time for the workers. The 5000 facilities were chosen to be representative of the entire non-agricultural business sector covered by the 1970 Occupational Safety and Health Act. Agricultural and public sector workers are therefore excluded from this study.

In response to a request from the author, NIOSH created a risk index for the 231 three digit Census occupations for which NOHS data are available. A total of 1721 chemicals are included in the full set of NIOSH-created hazard indexes based on the match between RTECS toxicology information and NOHS exposure information. The index used in this study was limited to the 114 chemicals with positive evidence of carcinogenicity. The occupational index is constructed by multiplying the RTECS-based toxicity index for each chemical by the NOHS-based estimate of the fraction of workers in the occupation exposed to that chemical, and then summing over all 114 chemicals. Chemicals for which exposures were reported by the NOHS engineers as "controlled" are weighted by a factor of 0.1; chemicals where exposures were reported as part time are weighted by a factor of 0.5. This manner of index construction is in accord with the general algorithm for index construction developed by the NIOSH staff, also described in Pedersen, Young, and Sundin (1983).

The young men's and young women's NLS are panel surveys conducted on regular intervals with a core of questions asked of each wave and special questions asked of particular waves. In the 1978 (men) and 1980 (women) waves, respondents were asked questions concerning exposure to "dangerous" working conditions and to "unhealthy conditions." No questions directly focused on the risk of cancer. For this study, a variable is constructed that takes the value 1 if the worker reported high level of exposure to "unhealthy conditions" and 0 if he or she reported no or only low level of exposure to unhealthy conditions, regardless of extent of exposure to dangerous conditions. Since the men's and women's surveys were conducted within two years of each other, were conducted in identical manners and contained identical questions, they are merged together for this study to provide a more representative sample of the entire working population. A total of 1837 NLS respondents were employed in the occupations for which cancer risk information was available. Of these, 22.4% reported a high level of exposure to unhealthy conditions.

The NLS quit measure is constructed as a variable taking the value 1 if the worker quit his or her job between 1978 and 1980 (men) or 1980 and 1982 (women). These waves of the NLS were interviewed only every two years. A prounion sentiment variable is constructed that takes the value 1 if the worker responded affirmatively to the question: "If an election were held with secret ballots, would you vote for or against having a union or employees association represent you?"

Demographic variables describing individual NLS respondents include race, sex, years of education, age, and the square of age. Worker-assessed job characteristics aside from risk to health and safety include dichotomous variables indicating whether the worker strongly denied that "the chances for promotion are good," "the skills you are learning would be valuable in getting a better job," and "the job security is good." Other job and worker characteristics include the logarithm of hourly earnings, years of tenure, current union status, location in the Southeast, and location within a Standard Metropolitan Statistical Area (SMSA). The union status variable is used in the quit regression but not in the prounion sentiment regression.

Results

Table 1 presents the 20 occupations with the highest risk of cancer, plus the number of carcinogens present and the cancer index itself. These high-risk occupations span both the blue and white collar sectors of the economy and include both high and low skill positions.

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TABLE 1.—OCCUPATIONS WITH GREATEST EXPOSURE TO CARCINOGENS

Occupation	No. of Carcinogens	Cancer Index
Agriculture and Biological Technicians	17	.170
Biological Scientists	14	.125
Clinical Laboratory Technologist		
and Technicians	22	.120
Chemists	58	.095
Mixing Operatives	60	.088
Hairdressers and Cosmetologists	2	.084
Housekeepers, Exc. Private Household	5	.064
Millwrights	17	.061
Pharmacists	6	.058
Chemical Technicians	43	.058
Painters, Construction and Maintenance	14	.057
Aircraft Mechanics	17	.056
Pattern and Model Makers	13	.053
Machinists	22	.045
Brick Masons and Stone Masons	5	.044
Air Conditioning, Heating, and Refrigeration		
Mechanics	11	.044
Miscellaneous Mechanics and Repairmen	13	.042
Tool and Die Makers	20	.042
Jewelers and Watchmakers	3	.040
Boilermakers	7	.037

TABLE 2.—LOGISTIC PARAMETER ESTIMATES OF DETERMINANTS OF WORKER HEALTH HAZARD PERCEPTIONS (ASYMPTOTIC STANDARD ERRORS IN PARENTHESES)

*	,
Cancer Index	10.52
	(1.40)
Worker is Black	0.389
	(0.134)
Worker is Female	-0.568
	(0.126)
Years of Education	-0.117
	(0.023)
Years of Age	-0.043
_	(0.395)
Age Squared	0.00072
•	(0.00624)
Intercept	0.816
•	(6.200)
-2 Log Likelihood	1978
Mean of Dep. Variable	0.224
1	

Table 2 presents logistic parameter estimates for the determinants of worker assessments of the risk of occupational disease. Workers employed in occupations with high cancer risk indexes are significantly more likely to describe themselves as facing high risk of disease than are comparable workers employed in occupations with low risk indexes. A four standard deviation increase in the cancer risk index is associated with a 26.4 percentage point increase in the probability a worker will report serious risk of work-related disease. Black workers are significantly more likely than whites to report unhealthy conditions; women are significantly less likely to report exposure to hazard than are men. Years of education are negatively associated

with reported hazard exposure, presumably due to the assignment of more educated workers to relatively healthy jobs within particular occupations.

The association between risk exposure and worker strategies is presented in table 3. Quits are positively correlated both with the cancer index and with worker-assessed exposure to unhealthy conditions. A four standard deviation increase in the cancer index would increase the probability of quitting by 5.6 percentage points. Workers reporting substantial exposure to "unhealthy conditions" are 3.4 percentage points more likely to quit than are otherwise comparable workers not so exposed. These effects are statistically significant at the 0.05 significance level using a onetailed test. The effects of the other variables in the exit regressions are consistent with those reported in other studies of worker quits (e.g., Viscusi, 1979; Freeman, 1980). Unionized workers, those with higher wage rates, and those with more years of employment tenure are significantly less likely to quit between subsequent interviews than are nonunion workers, those with lower earnings, and those with less tenure. Workers in jobs offering few promotion possibilities are more likely to quit than are workers with good prospects for promotion. Black workers and older workers are less likely to quit than are white and younger workers, other things equal.

For both objective and subjective measures of occupational health hazards, workers at greater risk are more likely than otherwise comparable workers at less risk to report prounion attitudes. According to the figures in the fourth column of table 3, a four standard

TABLE 3.—DETERMINANTS	OF EXIT AND	Voice Strategies:
DESCRIPTIVE STATISTICS AND	LOGISTIC PA	RAMETER ESTIMATES

	Mean	Logistic Parameter Estimates (asymptotic standard errors)				
	(S.D.)	\overline{QU}	QUITS		PROUNION	
Cancer Index	0.0229 (0.0376)	3.289 (1.797)		2.295 (1.679)		
Self-Reported Hazard Exposure	0.224 (0.417)	_	0.292 (0.173)	_	0.475 (0.148)	
Log Earnings	1.813 (0.440)	-0.715 (0.193)	-0.663 (0.189)	0.241 (0.170)	0.251 (0.169)	
Unionized	0.357 (0.479)	-0.442 (0.169)	-0.468 (0.170)			
No Job Training	0.265 (0.441)	-0.230 (0.177)	-0.239 (0.177)	0.446 (0.143)	0.423 (0.144)	
No Promotions	0.494 (0.500)	0.465 (0.152)	0.463 (0.152)	0.481 (0.131)	0.453 (0.132)	
No Job Security	0.219 (0.413)	-0.055 (0.171)	-0.081 (0.171)	0.114 (0.157)	0.080 (0.158)	
Years of Tenure	4.69 (4.08)	-0.225 (0.026)	-0.227 (0.027)	0.038 (0.016)	0.037 (0.016)	
Worker is Black	0.225 (0.418)	-0.451 (0.196)	-0.479 (0.196)	1.353 (0.161)	1.313 (0.162)	
Worker is Female	0.412 (0.492)	-0.045 (0.157)	0.015 (0.154)	-0.251 (0.137)	-0.168 (0.135)	
Years of Education	13.28 (2.56)	0.026 (0.030)	0.036 (0.030)	-0.077 (0.025)	-0.062 (0.025)	
Years of Age	31.2 (3.1)	-0.951 (0.483)	-0.921 (0.482)	0.079 (0.429)	0.122 (0.432)	
Age Squared	982.8 (196.1)	0.015 (0.008)	0.014 (0.008)	-0.0015 (0.0068)	-0.0022 (0.0068)	
Southeast	0.338 (0.488)	0.068 (0.156)	0.061 (0.156)	-0.294 (0.139)	-0.276 (0.139)	
SMSA	0.725 (0.447)	0.159 (0.165)	0.143 (0.165)	0.206 (0.144)	0.186 (0.145)	
Intercept	_	15.19 (7.56)	14.52 (7.54)	-1.381 (6.748)	-2.310 (6.784)	
-2 Log Likelihood Mean of Dep. Variable	_	1473 0.178	1471 0.178	1691 0.470	1684 0.470	

deviation increase in the cancer risk index would be associated with an 8.5 percentage point increase in the probability of reporting prounion sentiment. This effect is statistically significant at the 0.10 level using a one-tailed test. Workers reporting serious levels of exposure to unhealthy conditions are 11.8 percentage points more likely to report prounion sentiment than are those not reporting unhealthy conditions; this is significant at the 0.05 level using a one-tailed test.

Workers reporting no promotion possibilities and no meaningful training possibilities are more likely to report a willingness to vote in favor of union representation than are comparable workers not reporting these undesirable job characteristics. Levels of wages are positively associated with worker willingness to vote prounion. Black workers are overwhelmingly more likely to vote prounion than are white workers. Southerners and workers with more years of education are

less likely to favor unionism than are non-Southerners and those with fewer years of education.

Conclusion

The results presented in this paper indicate that workers recognize at least some of the cancer risks they face on the job. This finding is especially interesting since it is based on data gathered in the late 1970s before the main period of growth in "right-to-know" and related policy strategies designed to increase worker hazard awareness. The 1980s have witnessed an explosion of policy initiatives at the local, state, and federal levels that grant workers improved access to hazard information, and particularly to information on occupational carcinogens (Ashford and Caldart, 1985). More recent data might show an even stronger correlation between objective and subjective measures of haz-

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ard exposure, at least if collected among workers benefiting from meaningful training programs. The exit and voice responses documented using the NLS data suggest that, if appropriately informed, workers will respond actively to long-term health hazards as well as to immediate injury risks.

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RISK ATTITUDES IN FIRST-PRICE AUCTION EXPERIMENTS: A BAYESIAN ANALYSIS

Glenn W. Harrison*

Abstract—Non-cooperative bidding theory for sealed-bid auctions generally implies testable predictions that are conditioned on the risk attitudes of agents. Received laboratory experiments that purport to test this theory do not generally control for the risk attitudes of subjects. Those experiments exhibit behavior inconsistent with popular bidding models that assume that agents have the same aversion to risk or are all risk neutral. This paper constructs an explicit Bayesian prior distribution for the risk attitudes of experimental subjects and reconsiders the experimental results. It finds that observed bidding behavior is still inconsistent with the Nash predictions when explicit prior weights are attached to alternative assumptions about subject risk attitudes. Thus one cannot account for observed bidding anomalies by appealing to uncontrolled nuisance variables such as risk attitudes.

Non-cooperative bidding theory for sealed-bid auctions generally implies testable predictions that are conditioned on the risk attitudes of agents. Archetypical of this result is the Nash Equilibrium prediction for First Price auctions for an object that is valued by agents in an independent and private manner. Received laboratory experiments that purport to test this theory do not generally control for the risk attitudes of subjects. Those experiments exhibit behavior inconsistent with popular bidding models that assume that agents have the same aversion to risk or are all risk neutral. In this paper we construct an explicit prior

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* University of South Carolina.

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distribution for the risk attitudes of experimental subjects and reconsider the experimental results. We find that observed bidding behavior is indeed consistent with the Nash predictions when explicit prior weights are attached to alternative assumptions about subject risk aversion. However, when one allows for risk loving subjects as well, observed behavior is inconsistent with Nash predictions. Thus one cannot account for observed bidding anomalies by appealing to uncontrolled nuisance variables such as risk attitudes.

In section I we consider a specific Nash Equilibrium (NE) bidding model due to Cox, Roberson and Smith (1982) and Cox, Smith and Walker (1988) that clearly illustrates the risk-sensitivity of the theoretical predictions. In section II we provide independent evidence of the risk attitudes of experimental subjects in a test for risk attitudes developed by Harrison (1986a). This evidence allows us to construct an explicit prior probability density function over the coefficient of (constant relative) risk attitudes employed in the specific bidding model of section I. In section III we reconsider the evidence from the First Price (FP) experiments reported in Cox, Roberson and Smith (1982) and Cox, Smith and Walker (1983a, 1983b).

I. A Specific Bidding Model

Cox, Roberson and Smith (1982), hereafter CRS, present a model based on a power function utility specification for agent *i*:

$$U_i(y) = y_i^r \tag{1}$$

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